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OUTLINE OF THE TUBE PLAN OF STRUCTURE OF THE ANIMAL BODY

By J. S. FOOTE

WITH SIX PLATES

The recognition of a definite plan underlying minute structures is as essential to the understanding of body construction as to that of the tissues themselves. Tissues and cells do not exist separately in the body, but are associated together as a cooperative community, each one bearing some particular relationship to all the others. If design is omitted they are confusing and difficult to remember; but if the design is known their various positions and varieties become reasonable and easy to fix in the mind.

It will simplify matters very much if there can be found some one plan of structure which is sufficiently common to the greater number of organs of the body to become a fundamental constructive unit in their formation. This plan of structure is to be found in the tube. The development of the vertebrate kingdom of animals calls attention to this fact. The small dimensions of the Protozoa enabled them to continue themselves and exhibit their phenomena of life without the presence of a central cavity; but as physiological division of labor advanced in accordance with an increase of animal mass a time came when a central cavity was necessary for the nutrition of the animal and from that time the tube became the basis of structure. It was foreshadowed as far back as *Euglena viridis*—a single-celled organism in which there was a slight indentation in the anterior end of the creature and this was set aside as a food tube of entrance to the small body. This simple tube in the low forms of life developing into a complex system in the higher and highest forms indicates the line of ascent along which animal progress has made its way, and we find that the worm, tunicate, fish, amphibian, reptile, bird, and mammal—chief divisions of the animal kingdom—all present the tube as the fundamental structure of the body and of most of its viscera.

Embryological development also reveals the tube plan in all its phases. After fertilization has occurred and the blastoderm has been formed the whole period of prenatal life is concerned with the tube formations and adjustments and when the creature is born, it is born as a large tube within which are arranged in the form of viscera a vast number of small tubes of all magnitudes. Both racial and individual developments are tube developments and the kind of tube produced depends upon the functional requirements of the animal. The vertebrate animals are all practically constructed on the same plan. They are composed of two tubes: the larger one containing the thoracic and the abdominal viscera separated by the diaphragm; the other, the smaller, enclosing the brain and spinal cord.

THE VISCERA COMPOSED OF SYSTEMS OF TUBES

By a simple dissection we may satisfy ourselves that most of the great system of the body are large tubes, as, for example, the respiratory, digestive, genital, urinary, vascular. By further analysis these large tubes or systems are found to contain many small ones: these small tubes are joined together in various ways by connective tissue and form the organs. Thus the respiratory system is composed of a large tube, the trachea, which divides and subdivides into a great number of small tubes, the ultimate terminations of which are the alveoli of the lungs. The digestive system is composed of a large tube, the alimentary canal, the functional lining of which is arranged in the form of simple and compound tubular glands which are small tubes. The genital system is composed of a large tube containing in its different divisions many small ones. The urinary system is composed of a large tube some parts of which exhibit a most complex system of small ones. The vascular system is composed of a large tube which gradually decreases in size and forms small ones. The secretory system is composed of large tubes which ultimately terminate in a vast number of small ones, the acini. The viscera then are for the most part aggregations of tubes and in many instances the structure and function of one of them is sufficient for the whole. If we can understand the structure and function of one air cell we can understand the structure and function of the lung. If we know the structure and function of one lobule of the liver or of any secreting or excreting gland we know the structure and function of any of those glands taken as a whole.

THE VISCERAL TUBES ARRANGED IN FIVE CLASSES

The numerous visceral tubes vary somewhat in their structure as they do in their function. But if we examine them all and classify them on the basis of structural agreement, we will find that nearly all the tubes of the different viscera may be arranged under five classes. These five classes will be found to differ from each other by the presence or absence of some definite structure. The thickness of the wall of any tube depends upon what is required of it. It may be thick like the uterus or thin like a capillary, but in any case the walls are composed of some combination of the tissues arranged in the form of coats which may be divided into layers. For the sake of convenience we may begin with that class which has the greatest number of coats, which is four, and by a process of subtraction arrive at a class with three coats—then two—then one—then one layer. These tubes may be designated as four-coated, three-coated, two-coated, one-coated, and one-layer tubes. In each tube structure the coat numbered 1, is the outside coat and the tube section is so placed that its inner epithelial lining is uppermost. The coats of the five tube classes are given below:

Coats of a Four-Coated Tube.
4. Epithelial.
3. Subepithelial.
2. Muscular.
1. Connective tissue.

Coats of a Three-Coated Tube.
3. Epithelial.
2. Muscular.
1. Connective tissue.

Coats of a Two-Coated Tube.
2. Epithelial.
1. Connective tissue.

One-Coated Tube.
b. Epithelial.
a. Basement.
} Two layers.

One-Layer Tube. *b*. Epithelial.

It is thought that the coats and hence the structure of these tubes will be better understood if they are based upon the functions of the tubes.

In microscopical sections the purpose of the structures seen does not appear and so no particular reason for the existence of any coat is apparent and the coats are meaningless to the observer. If the object of the tube is known then the structure becomes reasonable and consequently more easily remembered. Structure does not indicate function. For example there is nothing about a specimen of muscle to show that it ever contracted nor would it be possible by an examination of it carried even to the limits of microscopical investigation to prove that it could contract. But knowing that it does contract its ultimate structure then becomes a reasonable one. The same is true concerning any other structure. The various tube structures or coats may be considered from this viewpoint.

Four-Coated Tube

The alimentary canal is the only tube of this class.

1. *Connective tissue coat.*—This is a thin layer of connective tissue in the form of a serous membrane which surrounds the tube for the most part from the lower end of the oesophagus to the rectum. This coat of the oesophagus consists of the connective tissue which supports the tube and may or may not be considered a distinct coat. By means of this coat the tube is supported by attachments to the skeleton and provided with a blood and lymph circulation.

2. *Muscular coat.*—This is composed of two layers of muscle throughout the whole length of the alimentary canal except at the cardiac end of the stomach, where there are three. In the upper half of the oesophagus the muscle is striped voluntary, in the other portion smooth. Here a motor tube is required because progressive motion of the contents in a certain direction is necessary. This can be accomplished only by a contractile tissue and this must be arranged according to some definite plan. In most motor tubes, two layers of muscle are sufficient, an external longitudinal and internal circular. In a few tubes three layers are found. Of the two layers the external longitudinal by contraction shortens the tube and makes it rigid while the internal circular by a wave of contraction from above downward propels the contents toward the lower end of the tube. In the cardiac stomach the internal oblique layer of muscle is composed of a few radiating strands over the fundus, the effect of which is not important. The layers of muscles are joined together by a thin connective tissue which carries small blood and

lymph vessels and a plexus of nerves called the plexus of Auerbach. In the pyloric end of the stomach the internal circular layer is thickened to form the *sphincter pylori.* The character of the contents of a tube governs the amount of muscle which it contains and when the contents consist of a small amount of liquid, ciliary motion is sufficient. The contents of the four-coated tube are large. There is no force behind them and therefore a well-developed muscular apparatus must be provided in order to move the contents from one end of it to the other.

3. *Subepithelial coat.*—This is composed of areolar tissue which joins the muscular and epithelial coats and contains blood vessels, lymphatics, a plexus of nerves called the plexus of Meissner, and in two places, *viz.,* oesophagus and duodenum, secreting glands. While this coat unites the epithelial and muscular coats it allows freedom of motion of the former upon the latter on account of its areolar character. It is widest in the stomach and the epithelial coat is more freely movable than in other parts. It contains parts of Peyer's patches which are confined to the lower portion of the small intestine and which extend into the epithelial coat.

4. *Epithelial coat.*—This coat is also called mucous membrane or *mucosa.* The term epithelial coat is preferred because it does not lead one to think that its chief function is mucin producing, but may be any secreting function. It is made up of a *muscularis mucosae* which is composed of two very thin layers, an external longitudinal and internal circular, of smooth muscle, and of a connective tissue base, containing in some places diffuse masses of lymphoid tissue, as in the stomach, in others, as small and large intestines, solitary glands and parts of Peyer's patches, blood and lymph vessels. Resting upon the latter is a stratified pavement epithelium as in the oesophagus, or embedded within it gastric glands as in the stomach, crypts of Lieberkühn and villi as in the small intestine, crypts of Lieberkühn with many goblet cells as in the large intestine, and lymphoid tissue in which are incomplete crypts as in the vermiform appendix. The *muscularis mucosae* distinguishes this type of tube from all others. In the examination of a section if we find it we know we are examining a four-coated tube and that this belongs only to the alimentary canal.

The *muscularis mucosae* is required in this tube for the proper adjustment of the epithelial structure to the moving contents and for

the purpose of shortening the villi of the small intestine, as a result of which the contents of the central lacteals are set in motion. There is perhaps no other tube in which the adaptive function of the *muscularis mucosae* would be of any advantage to the tube because there is no other tube having the same character of contents. If there was no *muscularis mucosae* in the alimentary canal the epithelial lining would be pouched by the driving force of the muscular coat and having no means of withdrawing itself would be torn.

The four-coated tube then is a motor tube adapted to the progressive motion of its contents and also to the application of its epithelial lining to the contents. The various organs which belong to this tube together with their structures are given in the following outlines. (Table A.)

Constructive Method

Since so many of the organs of the body are tubes and the walls of the tubes are composed of coats and layers, a constructive method of learning these structures may be employed. The various coats and layers are all drawn on the same curve, printed and cut out of suitable material. By placing these parts together according to the arrangements in the outlines the different organs of the tube formation may be constructed. It is believed that the actual construction of an organ by means of its parts fixes it in the mind as a reality. The simple matter of handling the coats and layers and placing them in the positions which they naturally occupy discloses a plan of structure and furnishes a reason for many of their actions.

Thus, referring to Plate IX, if we take 14, 11, 8, 4, 6, 9 and 10, and arrange them according to the outline of a four-coated tube we shall have the pyloric end of the stomach. (See Plate XIV, fig. 1.) In a similar manner any tube may be constructed. The numbers at the ends of the coats in the plates are for convenience in the illustration of the method and the order is not significant; thus fig. 11 indicates the external longitudinal smooth muscle. The fine details of structure are to be worked out in the laboratory. The object of this method is to give as much prominence to the plan of formation as to the tissues and cells, and this can be accomplished better by the building process than by any other. Connective tissue, smooth muscle, epithelium, blood vessels, nerves, and lymphatics do not make a stomach unless they are arranged according to a definite design,

and the design is as important as the tissues. The models are made on a general formula, that is, the connective tissue coat, smooth muscle, *muscularis mucosae,* and subepithelial coats may be used to build up any tube containing these parts. The teacher will call attention to variations. After constructing the tubes according to the outlines the microscopical section is examined in detail. The outlines give a word picture of the structure, the models the design of the structure, and the microscopic section the real structure. From the structure and function of the four-coated tube it is evident that some variation in structure will be necessary in order to adapt other tubes to different functions. There is no other class of tube in which a *muscularis mucosae* is necessary, inasmuch as the contents of all other tubes are small in amount and liquid in character, without undissolved masses, except perhaps the uterus in labor, and therefore the adaptation of the epithelial lining would not be required.

Other Tube Classes

If the *muscularis mucosae* is taken from the four-coated tube there is nothing to separate the epithelial coat from the sub-epithelial and hence the epithelial coat with the connective tissue coat underneath it may be considered as one. This makes a three-coated tube. It is a three-coated tube in function as well as structure. It is still a motor tube and has two sets of motor apparatus, *viz.,* smooth muscular coat and cilia. The muscular coat may have one, two, or three layers. The uterus, vas deferens, lower ureter, and bladder have three layers; the Fallopian tube, vagina, epididymis, seminal vesicle, upper ureter, and any large duct, have two layers; the artery, vein, and large lymphatic, one. The larger blood vessels do not have the definite coated arrangement, but have smooth muscle and elastic tissue intermixed. The Fallopian tube, uterus, epididymis, vas deferens, and bronchus have cilia and hence are provided with the two sets of motor apparatus. The presence of a muscular coat in the walls of these tubes shows that their contents are continually or intermittently in motion and that considerable force may be required to move the contents. The presence of a ciliated lining in some of them shows that the contents may be very small and very little force is required to move them. The presence of both muscle and cilia shows that the contents may be large and moved with difficulty, or small and easily moved. The circulatory tubes differ from other tubes in this re-

spect—that their contents are propelled by a force from behind and hence the muscular coat arrangement is not necessary. In none of these tubes would a *muscularis mucosae* be of any use. In the blood vessels and bladder a hydrostatic pressure exerted in all directions would not demand local adaptation of the enclosing surface. In the genital and respiratory tubes, epithelial adaptation to contents at ordinary times would do nothing and at the times when the muscular coat was at work could accomplish nothing. The epithelial coat has a connective tissue foundation and carries blood vessels, nerves, and lymphatics; but in no case, secreting glands. The epithelium varies according to the location of the tube. Nearly all varieties are found. The outside connective-tissue coat may contain plates of hyaline cartilage and secreting glands as in the bronchi. Here open tubes are required. The systems and organs which belong to the three-coated tube may be found in the following outline: (See Table B.)

The eye is a modified adaptation of the three-coated tube. Its diameters are nearly equal as the organ is nearly spherical. It is a combination of the segments of two spheres of different curvatures. It is not a motor tube and therefore has no regular muscular coat. However the three-coated tube arrangement is still preserved, as appears in the table following. (Table C, upper part.)

Plate X represents the structures in the outline of a three-coated tube. These organs may be built up by using the coats and layers of both plates. For example, place in order of outlines, Pl. IX, figs. 14, 11, 8; Pl. XI, figs. 25, 31, and the organ will be the epididymis. (See fig. 2, Pl. XIV.)

This completes the muscular tubes. If all the muscular layers be taken from the three-coated tube there will remain the epithelial and connective tissue coats. If C-shaped rings of hyaline cartilage are introduced into the connective tissue coat which also contains secreting glands, a two-coated tube will be formed. To this class belong the trachea and large bronchi, as is seen in the outline which follows. (Table C, lower part.)

These organs may be built up as follows: Pl. X, fig. 15, and Pl. XI, figs. 33 and 27. (See fig. 3, Pl. XIV.) The essential requirements of this class of tubes are that it be constantly kept open, and that the very small liquid contents be moved toward the upper end. The first requirement is made possible by cartilaginous rings, the second by the ciliated epithelial lining. Between the ends of the

cartilage rings, a very little smooth muscle is found arranged in longitudinal and transverse layers. This muscle however evidently takes no part in the propulsion of the contents. If the cartilage is taken from the two-coated tube a single coat of two layers will remain which may be designated as a one-coated tube. This tube is composed of an epithelial layer on a basement membrane or upon a base of connective tissue containing blood vessels, nerves, and lymphatics, with or without secreting glands. These tubes are generally small and constitute the structural units of many organs. They may be united by connective tissue and form organs such as the kidney, testicle, ovary, secreting glands, lung, or may be in large expanded areas as in the skin and serous membranes, or may be in the form of a prolonged tube enclosed in a bony canal as in the ear. They form the *tubuli seminiferi,* Graafian follicle, *tubuli uriniferi,* capsule of Bowman, alveoli of lungs, acini of secreting glands, small ducts, skin, hair follicle, serous membranes, and vestibule, utriculus, sacculus, semi-circular canals, and cochlea of the ear. The ear may be considered a coiled tube mostly enclosed in bone. This type of tube is adapted by structure to the function of secretion and special sense. Secreting glands are all constructed upon the same plan, *viz:* a basement membrane with the circulation on one side of it, and epithelium on the other. This brings the epithelium as near as possible to the blood, a condition of structure absolutely essential for the act of secretion. A structureless basement membrane represents the smallest supporting structure which can be placed between a cell and its blood supply. What is true in regard to glandular structure is also true concerning structures of special sense. It is as essential that neuro-epithelium should be close to the blood stream as it is that secreting epithelium should be. All highly organized cells require such positions. The various organs which belong to this tube are given in the following outline: (See Table D.)

Place in the order of the outline of a one-coated tube, Pl. XI, fig. 33, and Pl. XIII, fig. 60, and the organ will be a secreting gland (see Pl. XIV, fig. 4). If the basement membrane and connective tissue are taken from the single-coated tube, the epithelium remains and this is always simple pavement and forms the single layer class of tube. It is the simplest tube in the body and to it belong the blood and lymph capillaries. It is composed of one layer of pavement epithelial cells which are united by cement (see Pl. XIV, fig. 5).

This is the thinnest structure which can be placed between two liquids and hence is best adapted to osmotic conditions and the processes of cell nutrition. (See outline which follows. Table D, latter part.) Looking over these five classes of tubes it may be seen that structurally

A four-coated tube minus a *muscularis mucosae* is a three-coated tube.

A three-coated tube minus its muscular coat and plus cartilage rings is a two-coated tube.

A two-coated tube minus its cartilage is a one-coated tube.

A one-coated tube minus its basement structures is a one-layer tube; that is, the *muscularis mucosae,* muscular coat, cartilage rings, and basement structures are the differentiating structures in the walls of tubes. There still remain certain parts of the body which apparently, at least, do not conform to the tube plan of structure. These parts are the nervous system, thymus, spleen, lymph nodes, and adrenals.

" In the development of the cerebro-spinal system the rudimentary part is formed from the thickened medullary parts of the involuted epiblast, the ridges of which rising from the surface of the epiblast, are united dorsally along the middle line so as to form a hollow medullary tube. This tube is wider at its anterior or cephalic extremity and this dilated portion is divided by partial constrictions into three primary cerebral vesicles which represent the anterior, middle, and posterior divisions of the brain. The spinal portion retains a more uniform cylindrical shape. The continuous cavity enclosed within the primitive medullary tube is the same with that which constitutes the central ventricles of the brain and central canal of the spinal cord." (Quain's Anatomy.) Thus the brain during its early existence is the dilated anterior portion of the primary medullated tube derived from an indentation of the epiblast and the spinal cord is the remainder of that tube. In the adult the central ventricles of the brain and canal of the spinal cord still remain, showing that a tube plan is the plan of formation, although many structural additions and modifications have been made. The ventricles and central canal are lined with simple ciliated epithelium (fifth ventricle lined with simple pavement). Structurally then the brain and cord are covered on the outside by a connective tissue layer (*pia mater*) and are lined with a simple epithelium like certain other

tubes. Functionally the tubular character is not so clearly marked. The brain is composed of an external layer of gray matter which generates impulses and an internal core of white matter which conducts those impulses. In the spinal cord this arrangement is reversed. Both are enclosed with a covering of bone. If both the brain and cord were solid, that is, had no central canal, an increased or decreased blood supply would produce pressure upon nervous tissue and inhibit their actions and cause a termination of nervous phenomena. A central canal is essential to the volumetric increase and decrease of these organs; so that, although the functions of these organs do not depend upon the specific character of the tube as in other organs of the five tube classes, yet structurally the tube plan is essential to the successful performance of function.

The thymus in its early development is almost like an epithelial gland and during that stage of development would be classified among the tube structures of the body like any other true gland: but about the end of the second year following birth it begins to retrograde and when the age of puberty is reached an adenoid structure has displaced the epithelium and atrophy reduces the organ to an inactive condition. Therefore during its active period it belongs to the secreting glands and to the one-coated tubes. During its retrogressive period it is not tubular.

Apparently the spleen does not belong to the tube organs. However it seems to be a vascular body structurally and functionally, for if its vascular tubes are not considered in its plan of structure the remaining parts are reduced to blood cells. Its trabeculae of smooth muscle suggest a relationship of force pump to the liver and the spleen would belong to the three-coated tubes.

The lymph nodes are composed of masses of lymphoid tissue around which are channels through which the lymph passes. These channels or sinuses are lined with endothelium which also lines the inner surface of the capsule and outer surface of the trabeculae; so that the channels are widened parts of the lymph vessels within the nodes. This places them under the one-layer tubes. As far as function is concerned the parts outside of the channels are reduced to the functions of lymphoid tissue or leucocytes.

The adrenals are composed of cells arranged in different ways according to the zones which characterize the structure. A tube plan is not sufficiently apparent in these organs to place them under a tube system.

CONCLUSIONS

That a proper conception of a tube is essential to the comprehension of an organ.

That design is as important as tissue or cell.

That most of the organs of the body can be arranged under five tube classes, *viz.:* four-coated, three-coated, two-coated, single-coated, and one-layer tubes.

That four-coated tubes are adapted to the progressive motion of their contents and to the application of their epithelial structures to the contents.

That three-coated tubes are adapted to the progressive motion of their contents when necessary.

That two-coated tubes are adapted to conditions which require open tubes.

That single-coated tubes are adapted to functions of secretion and special sense.

That one-layer tubes are adapted to osmotic conditions.

That these tubes can be constructed by models and the constructive process is a great help to the beginner.

TABLE A

		System	Four Coats	Organs		
				Upper Half of the Oesophagus	Lower Half of the Oesophagus	Duodenum
Four-coated Tube	Characterized by an epithelial structure on a connective tissue base and a *muscularis mucosæ* — a sub-epithelial coat enclosing blood and lymph vessels, nerves, with or without secreting glands, a muscular coat of two or three layers, and a connective tissue coat	Alimentary	4. Epithelial			4. *Villi*
				3. *Stratified pavement epithelium*	3. *Stratified pavement epithelium*	3. *Crypts*, goblet cells
				2. Connective tissue base, blood and lymph vessels	2. Connective tissue base, blood and lymph vessels	2. Connective tissue base, blood and lymph vessels, lymphoid tissue, solitary glands
				1. *Muscularis mucosæ*	1. *Muscularis mucosæ*	1. *Muscularis mucosæ, two layers*
			3. Sub-epithelial	Areolar tissue enclosing nerves, blood vessels, lymphatics, and *secreting glands*	Areolar tissue, enclosing nerves, blood vessels, lymphatics, and *secreting glands*	Areolar tissue, enclosing nerves, blood vessels, lymphatics, and *secreting glands*
			2. Muscular	2. Internal circular *striped voluntary*	2. Internal circular *smooth*	2. Internal circular *smooth*
				1. External longitudinal *striped voluntary*	1. External longitudinal *smooth*	1. External longitudinal *smooth*
			1. Fibrous serous	Connective tissue	Connective tissue	Connective tissue

TABLE A, *Continued*

	Four Coats	Organs				
		Cardiac End of the Stomach	Pyloric End of the Stomach	Jejunum and Ileum	Large Intestine	Vermiform Appendix
Four-coated Tube (Continued)	4. Epithelial	3. *Compound tubular glands* { *Short necks* / *Long bodies* } *Chief and parietal cells* 2. Connective tissue base, blood and lymph vessels, and lymphoid tissue 1. *Muscularis mucosae, two layers*	3. *Compound tubular glands* { *Long necks* / *Short bodies* } *Chief cells alone* 2. Connective tissue base, blood and lymph vessels, and lymphoid tissue 1. *Muscularis mucosae, two layers*	4. *Villi* 3. *Crypts*, goblet cells 2. Connective tissue base, blood and lymph vessels, *solitary glands*, and *Peyer's patches* 1. *Muscularis mucosae, two layers*	3. *Crypts*, goblet cells 2. Connective tissue base, blood and lymph vessels, solitary glands 1. *Muscularis mucosae, two layers*	3. *Incomplete types* 2. *Large amount of lymphoid tissue in nodules and diffuse masses* 1. *Muscularis mucosae*
	3. Sub-epithelial	Loose areolar tissue, enclosing blood vessels, lymphatics, and nerves	Loose areolar tissue, enclosing blood vessels, lymphatics, and nerves	Areolar tissue, enclosing nerves, blood vessels, and lymphatics	Areolar tissue, enclosing nerves, blood vessels, and lymphatics	Areolar tissue, enclosing nerves, blood vessels, and lymphatics
	2. Muscular	3. *Internal oblique smooth* 2. Middle circular *smooth* 1. External longitudinal *smooth*	2. Internal *circular thick smooth* 1. External longitudinal *smooth*	2. Internal circular *smooth* 1. External longitudinal *smooth*	2. Internal circular *smooth* 1. External longitudinal *smooth*	2. Internal circular *smooth* 1. External longitudinal *smooth, poorly developed*
	1. Fibrous Serous	Connective tissue	Connective tissue	Connective tissue	Connective tissue	Connective tissue

TABLE B

		Systems	Three Coats	Organs		
				Fallopian Tube	Uterus	Vagina
Three-coated Tube	Characterized by an epithelial structure on a connective tissue base containing blood and lymph vessels, nerves, with or without secreting glands; a muscular coat of one, two, or three layers, and a fibrous coat with or without cartilage and secreting glands	Large genital, urinary, respiratory, vascular, eye	3. Epithelial	2. *Simple ciliated epithelium in folds*	2. *Simple ciliated epithelium in tubular glands*	2. *Stratified pavement epithelium*, which also lines one-half of the cervix uteri
				1. Connective tissue cellular base, blood vessels, nerves, and lymphatics	1. Connective tissue cellular base thick, blood vessels, nerves, and lymphatics	1. Fibrous and elastic tissue, with secreting glands
			2. Muscular		3. *Internal longitudinal, smooth*	
				2. *Internal circular, smooth*	2. *Thick, middle, vascular circular, or oblique smooth*	2. *Internal circular, smooth*
				1. *External longitudinal, smooth*	1. *External longitudinal, smooth*	1. *External longitudinal, smooth*
			1. Fibrous	Connective tissue serous	Connective tissue, or serous coat	Connective tissue

TABLE B, *Continued*

	Three Coats	Organs				
		Vasa Efferentia of Testicle	Epididymis	Vas Deferens	Ureter	Bladder
Three-coated Tube (Continued)	3. Epithelial	*Stratified ciliated, alternating with stratified columnar epithelium*	2. *Stratified columnar ciliated epithelium*	2. *Partly simple ciliated* and *partly stratified ciliated columnar epithelium*	2. *Stratified transitional epithelium*	2. *Stratified transitional epithelium*
			1. Fibrous and elastic issue	1. Fibrous and elastic tissue	1. Areolar tissue with nerves, blood vessels, few lymphatics	1. Areolar tissue with nerves, blood vessels, few lymphatics
	2. Muscular	2. *Internal circular, smooth*	2. *Internal circular, smooth*		2. *Internal longitudinal, smooth* (Upper half)	
		1. *External longitudinal, smooth, poorly developed*	1. *Thin external longitudinal, smooth*		1. *External circular, smooth* (Upper half)	
				3. *Internal longitudinal, smooth*	3. *Internal longitudinal, smooth* (Lower half.)	3. *Internal longitudinal, smooth*
				2. *Middle circular, smooth*	2. *Middle circular, smooth* (Lower half.)	2. *Middle circular* or *oblique, smooth*
				1. *External longitudinal, smooth*	1. *External longitudinal, smooth* (Lower half.)	1. *External longitudinal, smooth*
	1. Fibrous	Connective tissue	Connective tissue	Connective tissue	Connective tissue, serous	Connective tissue, serous

TABLE B, *Continued*

	Three Coats	Organs				
		Artery	Vein	Lymphatic	Medium Bronchus	Bronchus Less Than 1 mm. in Diameter
Three-coated Tube (Continued)	3. Epithelial	3. *Endothelium* 2. Connective tissue base 1. *Fenestrated membrane of Henle*	3. *Endothelium* 2. *Very thin base of connective tissue* 1. *Incomplete fenestrated membrane of Henle*	2. *Endothelium* 1. Connective tissue base with few elastic fibers	3. *Stratified ciliated epithelium* 2. Basement membrane 1. Areolar tissue with blood vessels, nerves, lymphoid tissue	2. Ciliated epithelium gradually changing to respiratory as the bronchus approaches the air cell 1. Basement membrane
	2. Muscular	*A single circular layer of smooth muscle*, which in the aorta and large vessels is arranged in *alternating layers of elastic tissue and smooth muscle*	*A thin circular layer of smooth muscle*	*A single layer of smooth muscle circularly and obliquely arranged*	2. *A single circular layer of smooth muscle* 1. Areolar tissue, enclosing nerves, blood vessels, lymphatics, and *secreting glands*	Single layer of smooth muscle
	1. Fibrous	Connective tissue	Connective tissue	Connective tissue	*Fibrous tissue enclosing plates of hyaline cartilage*	Connective tissue

TABLE B, *Continued*

	Three Coats	Organs		
		Large Ducts	Seminal Vesicles	Corpus Spongiosum of Penis
Three-coated Tube (Continued)	3. Epithelial	2. *Simple columnar epithelium*	2. *Pseudo-Stratified columnar epithelium*	Prostatic—*Transitional epithelium*
		1. Connective tissue with blood vessels, nerves, lymphatics	1. Connective tissue with blood vessels, nerves, lymphatics	Membranous—*Stratified columnar* Meatus—*Stratified pavement*
	2. Muscular	2. *Internal circular, smooth*	2. *Internal circular, smooth*	*Erectile tissue, consisting of trabeculae, connective tissue, elastic fibers, and smooth muscle, enclosing a communicating system of spaces*
		1. *External longitudinal, smooth*	1. *External longitudinal, smooth*	
	1. Fibrous	Connective tissue	Connective tissue	Dense connective tissue

TABLE C

	Three Coats	A Modified Adaptation of the Tube							Lenses
Eye	3. Epithelial	Retina	10. *Pigment layer of epithelium* 9. *Layer of rods and cones* 8. *External limiting membran.* 7. *Outer nuclear layer* 6. *Outer molecular layer* 5. *Inner nuclear layer* 4. *Inner molecular layer* 3. *Layer of nerve cells* 2. *Layer of nerve fibers* 1. *Internal limiting membrane*						3. Vitreous humor
	2. Musculo-vascular	Choroid	4. Vitreous membrane 3. Lamina choriocapillaris 2. Lamina vasculosa 1. Lamina suprachoroidea	Ciliary body	5. Pigmented epithelium 4. Ciliary processes 3. Ciliary muscles 2. Blood vessels 1. Connective tissue	Iris	3. Posterior vitreous layer 2. Connective tissue and *ciliary muscle* 1. Anterior epithelium		2. Crystalline lens
	1. Fibrous	Sclera	Connective tissue	Cornea	5. *Simple cubical epithelium* 4. *Posterior elastic lamina* 3. *Tunica propria* 2. *Anterior elastic lamina* 1. *Stratified pavement epithelium*				1. Aqueous humor

		System	Two Coats	Organs
				Trachea and Large Bronchi
Two-coated Tube.	Characterized by an epithelial structure on a basement membrane and a base of connective tissue; and a fibrous coat enclosing C-shaped rings of hyaline cartilage, secreting glands, nerves, blood vessels and lymphatics	Trachea, large bronchi	2. Epithelial	3. *Stratified ciliated epithelium* 2. Basement membrane 1. Areolar tissue, in which are blood vessels, nerves, lymphatics, masses of lymphoid tissue
			1. Fibrous	*Fibrous tissue, enclosing C-shaped rings of hyaline cartilage and secreting glands.* Thin longitudinal and transverse muscles between ends of rings

TABLE D

		Systems	Organs			
			Testicle			
			One Coat of Two Layers	Tubuli Seminiferi	Lobules	Testicle
One-coated Tube	Characterized by an epithelial structure on a basement membrane, or base of connective tissue with or without secreting glands	Small genital, urinary, glandular, respiratory, skin, hair, follicle, auditory. Serous membrane	*a. Epithelium*	*Spermatozoa*, *Spermatids*, *Spermatocytes*, *Spermatogonia*, *Sustentacular*	Tubuli seminiferi united by stroma of connective tissue containing blood vessels, nerves, lymphatics	Lobules united by connective tissue containing blood vessels, lymphatics, nerves, and surrounded by a capsule
			b. Basement	*Structureless membrane*		

			Kidney				
			One Coat with Two Layers	Tubuli Uriniferi		Pyramids	Kidney
One-coated Tube	Characterized by an epithelial structure on a basement membrane, or base of connective tissue with or without secreting glands	Small genital, urinary, glandular, respiratory, skin, hair, follicle, auditory. Serous membrane	*a. Epithelium*	Simple pavement, cubical, rodded, flattened, columnar	*Capsule of Bowman*, *Neck*, *Proximal convoluted*, *Descending spiral*, *Descending straight*, *Henle's loop*, *Ascending spiral*, *Ascending straight*, *Irregular portion*, *Distal convoluted*, *Junctional portion*, *Duct of Bellini*	Tubuli uriniferi united by connective tissue containing blood vessels, nerves, lymphatics	Pyramids united by connective tissue columns called columns of Bertini containing blood vessels, nerves, lymphatics
			b. Basement	Structureless membrane			

TABLE D, *Continued*

	One Coat with Two Layers	Organs				
		Secreting Glands				
		Acini or Tubular Units of Structure	Lobules	Lobes	Secreting Glands	Secreting Glands of the Body
One-coated Tube (Continued)	a. Epithelium	*Simple Polygonal, Polyhedral, Columnar* or *Cubical*	Acini or tubular units of structure united by connective tissue containing blood vessels, nerves, and lymphatics	Lobules united by connective tissue containing blood vessels, nerves, and lymphatics	Lobes united by connective tissue containing blood vessels, nerves, and lymphatics	Thyroid, Parotid, Submaxillary, Sublingual, Glands in the subepithelial coats of organs, Compound tubular glands of stomach, Crypts of Lieberkühn, Liver, Pancreas, Sweat glands, Sebaceous, Mammary, Meibomian, Lachrymal, Prostate, Cowper's, Nabothian, Bartholin
	b. Basement	*Structureless Membrane*				
	One Coat with Two Layers	Lung		Ovary		
		Air Cells or Alveoli	Lung	Graafian Follicles	Ovary	
	a. Epithelium	*Simple Pavement, Epithelium of two Varieties—Clear and Granular*	Air cells or alveoli united by connective tissue containing blood vessels, nerves, and lymphatics	3. *Ovum* 2. *Discus Proligerus* 1. *Membrana Granulosa* Theca Folliculi—a wall derived from the stroma	Graafian follicles united by connective tissue cell stroma containing blood vessels, lymphatics, nerves, and surrounded by germinal cells	
	b. Basement	*Interlacing, Fibrous and Elastic tissue*				

TABLE D, *Continued*

	One Coat with two Layers	Organs		
		Small Ducts	Hair Follicle	Skin
One-coated Tube (Continued)	a. Epithelial	*Low Columnar* or *Cubical Epithelium*	*Int. root sheath* *Ext. root sheath* *Hyaline layer*	Stratified pavement epithelium as— *Stratum corneum* *Stratum lucidum* *Stratum granulosum* *Stratum mucosum* — Epidermis
	b. Basement	*Structureless membrane*	One or two layers of connective tissue	Fibrous and elastic tissues with blood vessels, lymphatics, nerves, nerve terminations, and *secreting glands* — Dermis

		Middle Ear		Internal Ear
		Tympanum	Eustachian Tubes	Vestibule-Utriculus-Sacculus
	a. Epithelial	*Simple, Pseudo-Stratified, Ciliated, Epithelium*	2. Cartilaginous — Stratified ciliated Epithelium, Goblet cells, Lymphoid tissue 1. Osseous — Simple pseudo-stratified Ciliated epithelium	2. Macula utriculi — *Hair cells*, *Sustentacular cells* 1. Remaining part — Low columnar epithelium
	b. Basement	Connective tissue with secreting glands	Connective tissue part of periosteum	Dense connective tissue

TABLE D, *Continued*

	One Coat of Two Layers	Organs	
		Internal Ear	
		Semicircular Canals	Cochlea
One-coated Tube (Continued)	a. Epithelial	Crista of ampulla: Hair cells, Sustentacular cells Remaining part: Simple Pavement epithelium	Scala vestibuli: Endothelium Scala media: *Pillar cells*, *Hair cells*, *Sustentacular cells* Scala tympani: *Endothelium*
	b. Basement	Connective tissue	Connective tissue
		Nasal Mucosa	Serous Membranes
	a. Epithelial	2. Respiratory part: 3. Stratified ciliated epithelium, 2. Goblet cells, 1. Racemose glands 1. Olfactory part: 2. *Olfactory cells*, 1. Sustentacular cells	*Endothelium between cells of which are found Stigmata and Stomata*
	b. Basement	Connective tissue	Connective tissue rich in lymph spaces, lymph capillaries, and lymph vessels

		Systems	One Layer	Organs
				Capillaries
One-layer Tube	Characterized by a single layer of epithelial cells joined together by cement	Small vascular and lymph	a. Epithelial	*Simple, Pavement*, or *Endothelium*

EXPLANATION OF PLATES

The plates are, to a certain extent, diagrammatic, for the sake of clearness in demonstration. It is not the purpose of this system to exhibit accuracy of structural details; but to present a constructive plan of visceral formation.

Plates IX–XIII inclusive, represent different tissues arranged in the form of layers drawn as far as possible from a general formula, with which the organs of the animal body may be constructed. The sole object is to make especially prominent the *plan* of structure. Plate XIV shows the five tube classes built up according to this system. The system is devised as a teaching method for beginners in histology.

Plate IX

Fig. 1. Epithelium of straight tubes of kidney.
Fig. 2. Internal longitudinal layer of smooth muscle.
Fig. 3. Internal oblique layer of smooth muscle.
Fig. 4. Circular smooth muscle.
Fig. 5. Subepithelial layer with Peyer's patches.
Fig. 6. Subepithelial layer—general.
Fig. 7. Basement membrane, structureless.
Fig. 8. Internal circular smooth muscle layer.
Fig. 9. Muscularis mucosae.
Fig. 10. Epithelial layer of pyloric stomach.
Fig. 11. External longitudinal cross section of smooth muscle.
Fig. 12. Internal circular striped (voluntary) muscle.
Fig. 13. External longitudinal striped (voluntary) muscle, cross section.
Fig. 14. Connective tissue.

Plate X

Fig. 15. Connective tissue enclosing C-shaped rings of hyaline cartilage and secreting glands.
Fig. 16. Connective tissue enclosing plates of hyaline cartilage and secreting glands.
Fig. 17. Epithelial and lymphoid layer of the vermiform appendix.
Fig. 18. Villi.
Fig. 19. Crypts of Lieberkühn.
Fig. 20. Epithelial layer of cardiac stomach.
Fig. 21. Stratified pavement epithelium of oesophagus.
Fig. 22. Subepithelial layer of duodenum.
Fig. 23. Subepithelial layer of oesophagus.
Fig. 24. Middle circular, vascular layer of smooth muscle.

PLATE IX

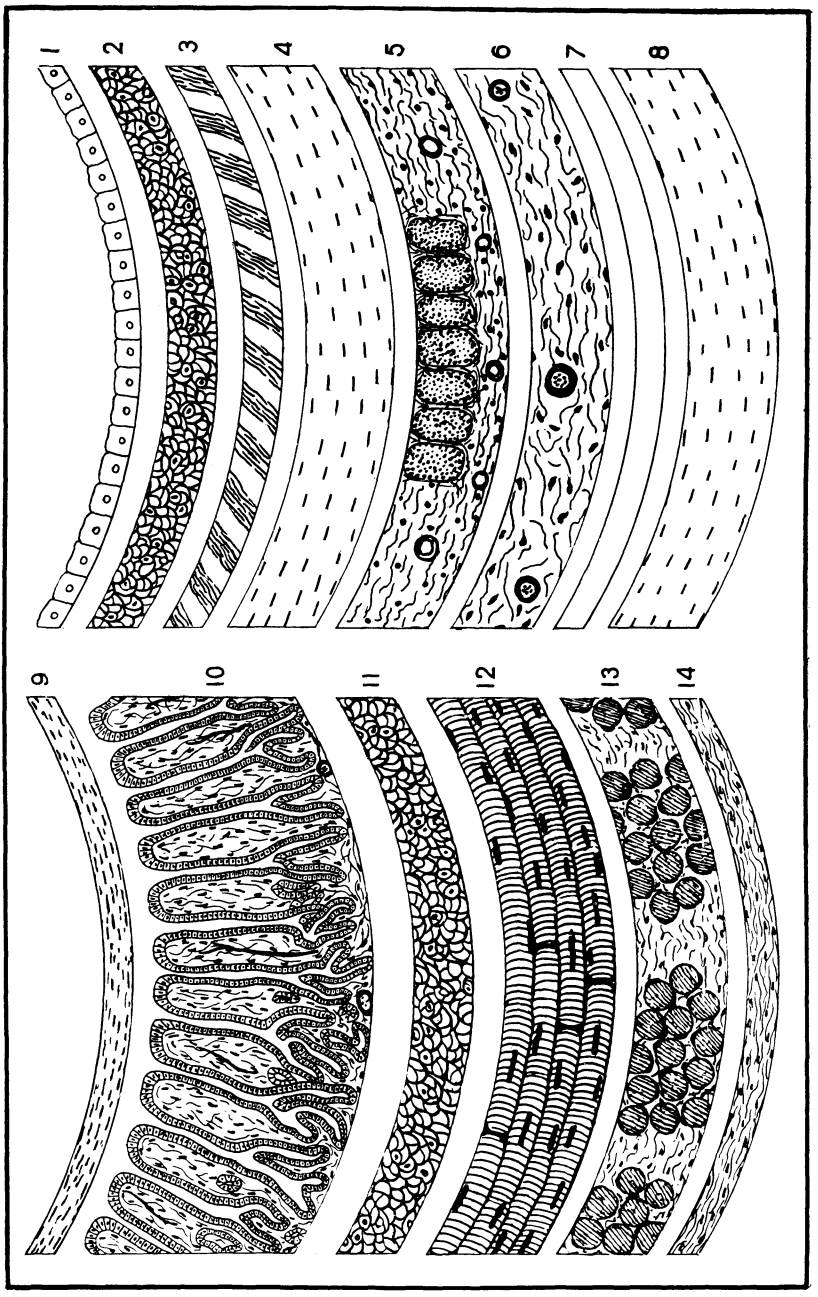

PLATE X

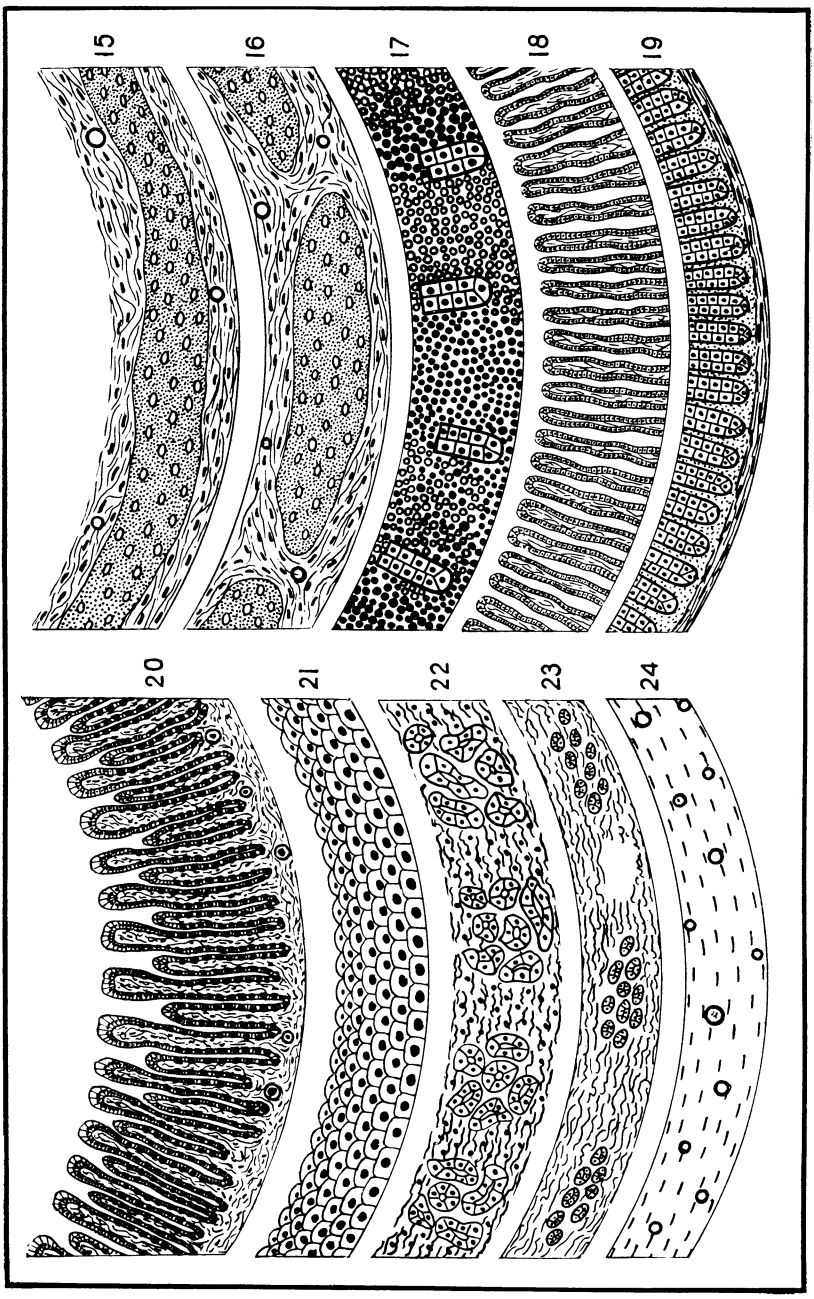

PLATE XI

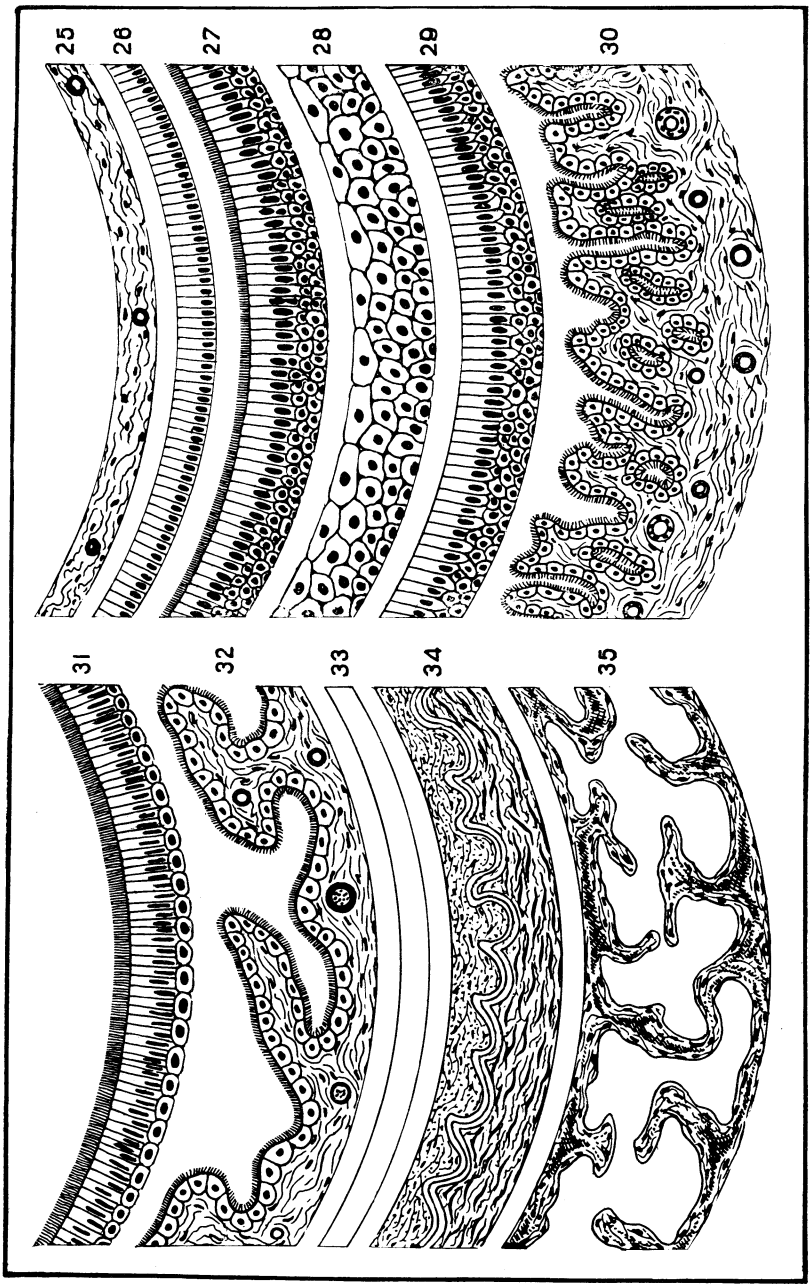

PLATE XII

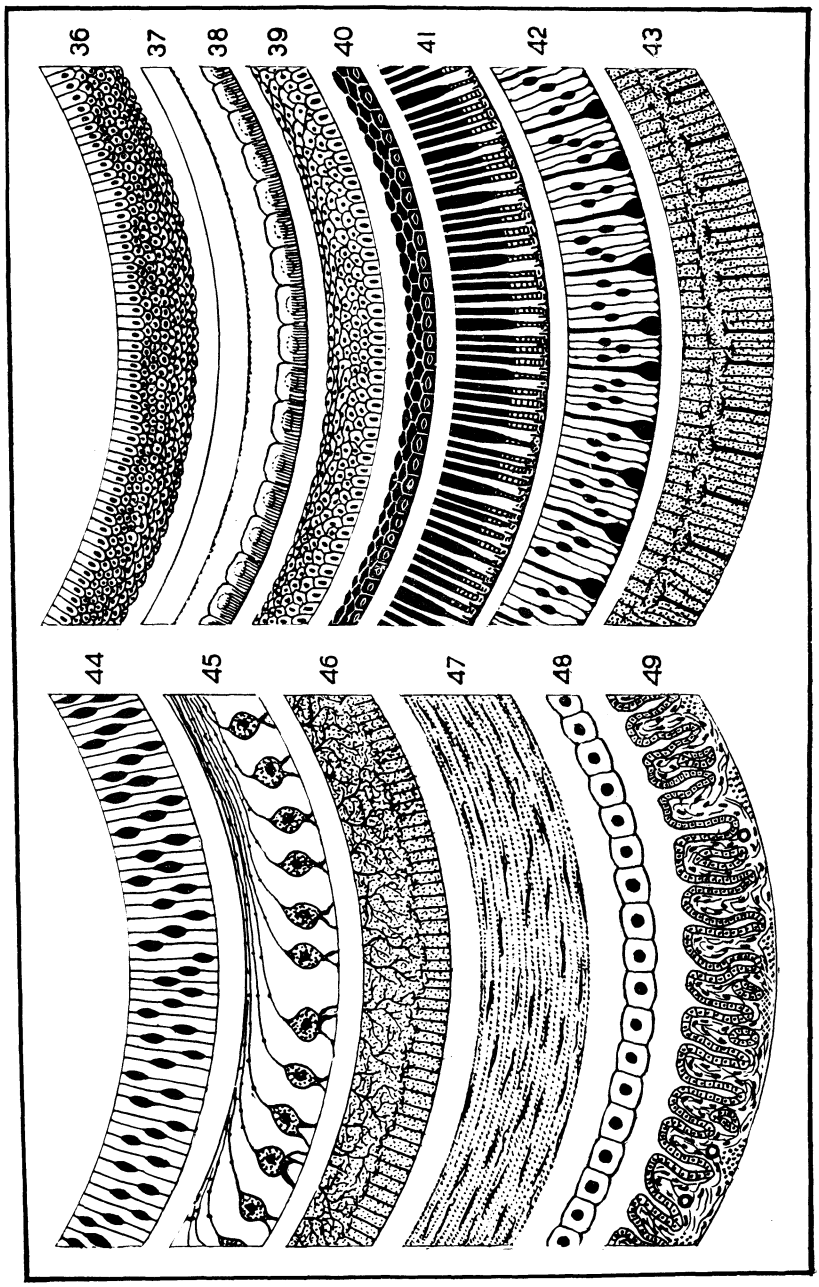

PLATE XIII

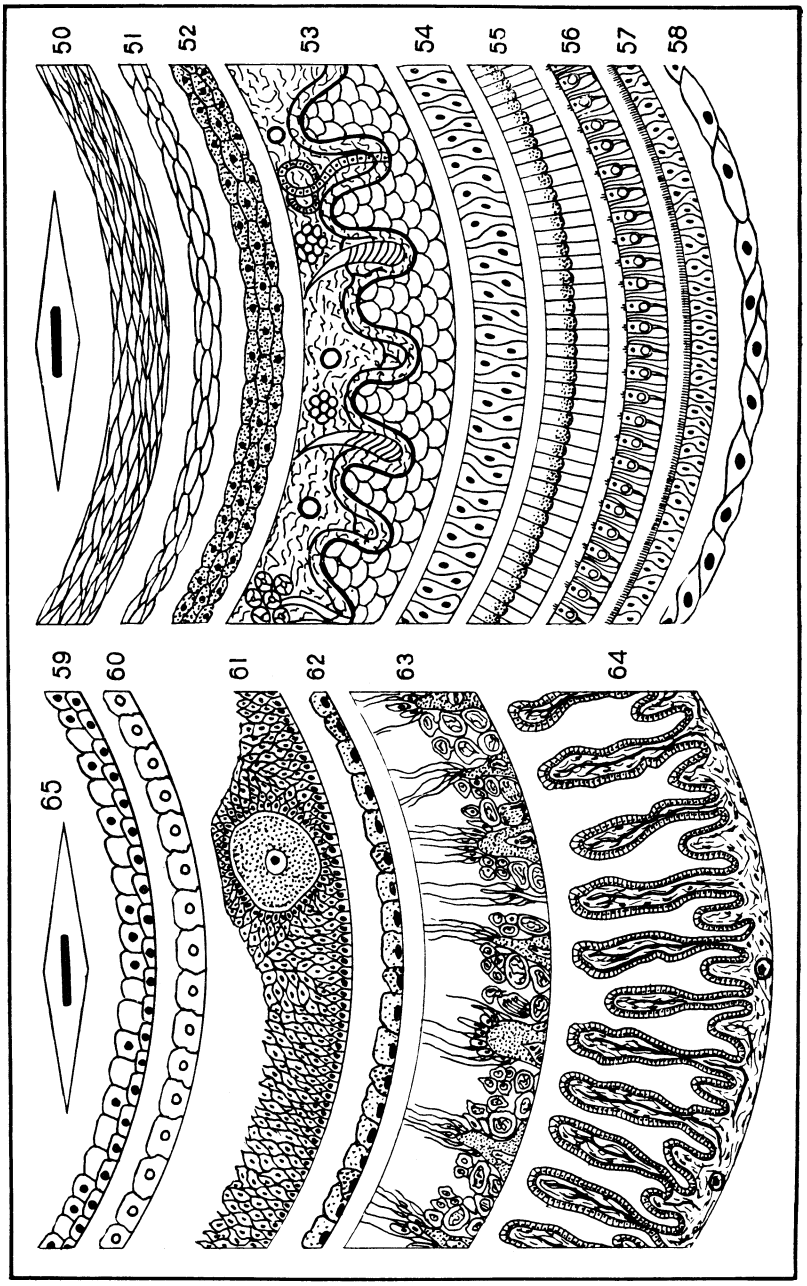

PLATE XIV

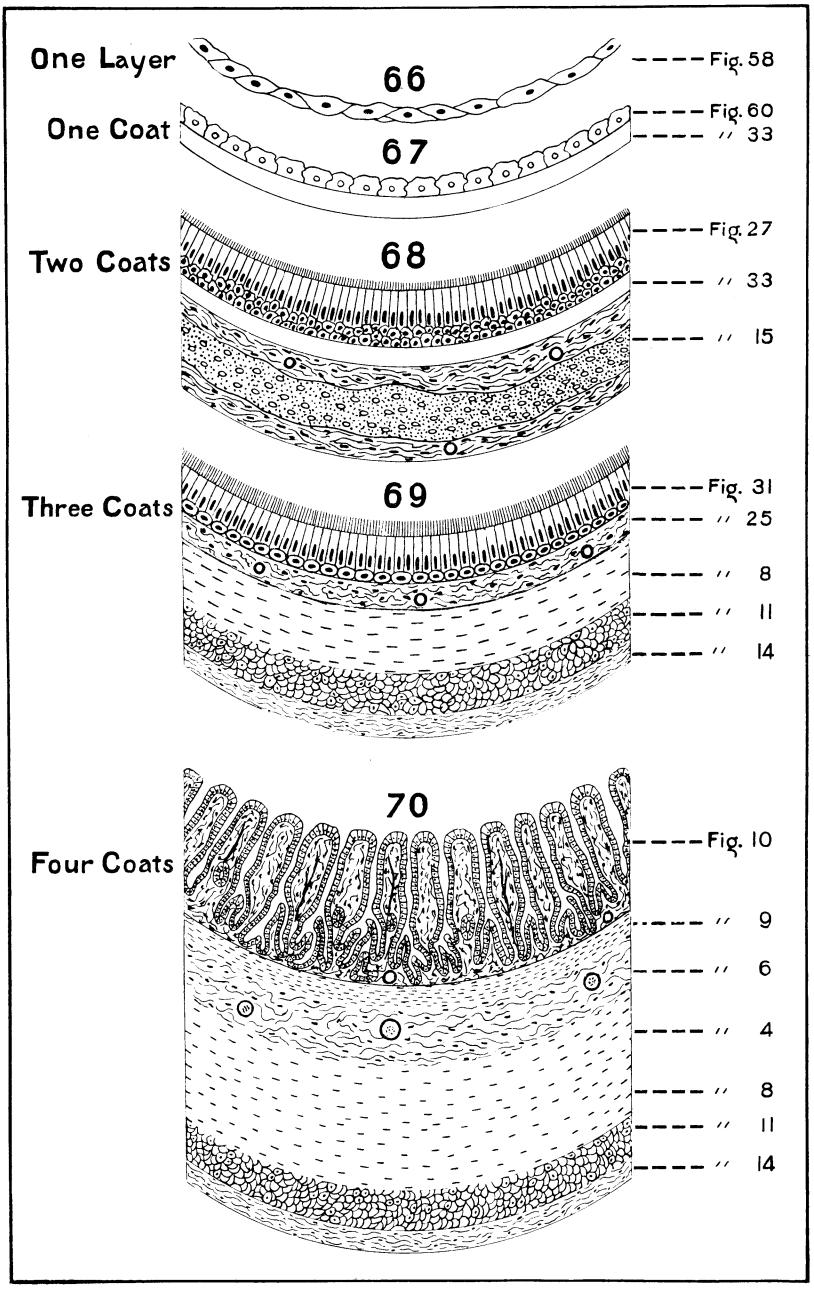
One Layer
66
Fig. 58
One Coat
67
Fig. 60
" 33
Two Coats
68
Fig. 27
" 33
" 15
Three Coats
69
Fig. 31
" 25
" 8
" 11
" 14
Four Coats
70
Fig. 10
" 9
" 6
" 4
" 8
" 11
" 14

Plate XI

Fig. 25. Connective tissue.
Fig. 26. Simple columnar epithelium.
Fig. 27. Stratified ciliated epithelium.
Fig. 28. Transitional epithelium.
Fig. 29. Stratified columnar epithelium.
Fig. 30. Epithelial coat of uterus.
Fig. 31. Stratified ciliated epithelium.
Fig. 32. Epithelial coat of Fallopian tube.
Fig. 33. Basement membrane.
Fig. 34. Circular smooth muscle of artery, fenestrated membrane.
Fig. 35. Erectile tissue.

Plate XII

Fig. 36. Stratified pavement epithelium.
Fig. 37. Elastic lamina.
Fig. 38. Rodded epithelium of kidney.
Fig. 39. Stratified pavement epithelium.
Fig. 40. Pigment layer of retina.
Fig. 41. Rods and cones of retina.
Fig. 42. Outer nuclear layer of retina.
Fig. 43. Outer molecular layer of retina.
Fig. 44. Inner nuclear layer of retina.
Fig. 45. Layer of nerve cells and fibers of retina.
Fig. 46. Inner molecular layer of retina.
Fig. 47. Tunica propria of cornea.
Fig. 48. Simple cubical epithelium.
Fig. 49. Epithelial coat of large intestine.

Plate XIII

Fig. 50. Stratum corneum.
Fig. 51. Stratum lucidum.
Fig. 52. Stratum granulosum.
Fig. 53. Dermis and epidermis.
Fig. 54. Pseudo-stratified ciliated epithelium.
Fig. 55. Pillar cells of ear.
Fig. 56. Hair cells of ear.
Fig. 57. Simple pseudo-stratified ciliated epithelium.
Fig. 58. Endothelium—capillary.
Fig. 59. Internal root sheath of hair follicle.
Fig. 60. Simple polygonal glandular epithelium.
Fig. 61. Graafian follicle.
Fig. 62. Respiratory epithelium.
Fig. 63. Epithelial layer of tubuli seminiferi.
Fig. 64. Epithelial layer of small intestine.
Fig. 65. Smooth muscle cells.

Plate XIV

The five classes of tubes are built up with the layers represented in plates IX–XIII.